RADIOACTIVE FALLOUT ON AGRICULTURE

IN TIME OF EMERGENCY

By

Frank A. Todd*

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RADIOACTIVE FALLOUT ON AGRICULTURE IN TIME OF EMERGENCY

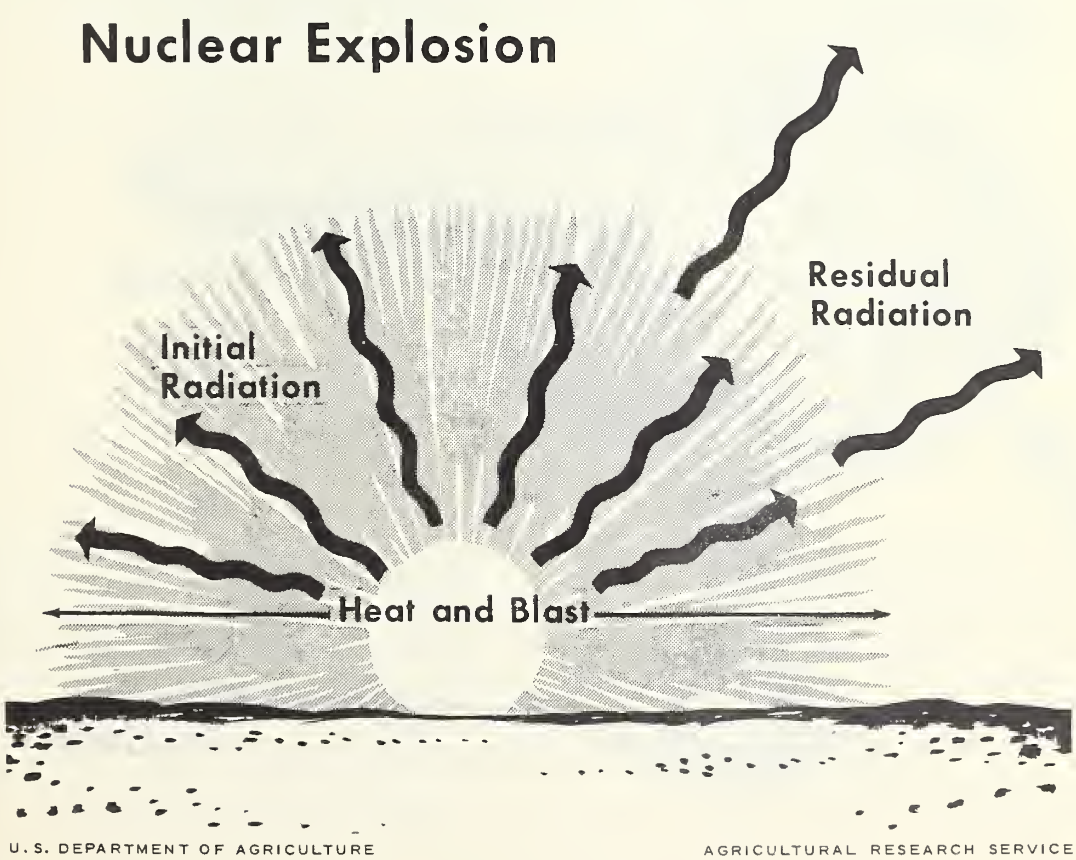
In an age when nuclear weapons are a reality, we as a nation should be prepared with as much knowledge as possible about protection and survival from an attack with these weapons. The primary responsibilities of agricultural leaders and farmers in such a catastrophe would be the protection of the farm people and the ability to produce the food and other crops necessary for existence.

Research is developing knowledge that would help to provide this protection. The study of nuclear weapons and their effects is a relatively new science, and it is understandable that not all of our information is definite at this time. However, research studies are extensive and our fund of dependable knowledge is growing rapidly.

One of the problems that is being widely studied to help agriculture survive a nuclear attack is the effect of radioactive fallout. And in approaching this problem we can start with the nuclear explosion itself.

NUCLEAR EXPLOSION

A nuclear explosion is accompanied by four destructive phenomena - blast, heat, initial radiation, and residual radiation. The first three are almost instantaneous while the fourth - residual radiation - produces its effects later and over a much longer period. (Figure 1).

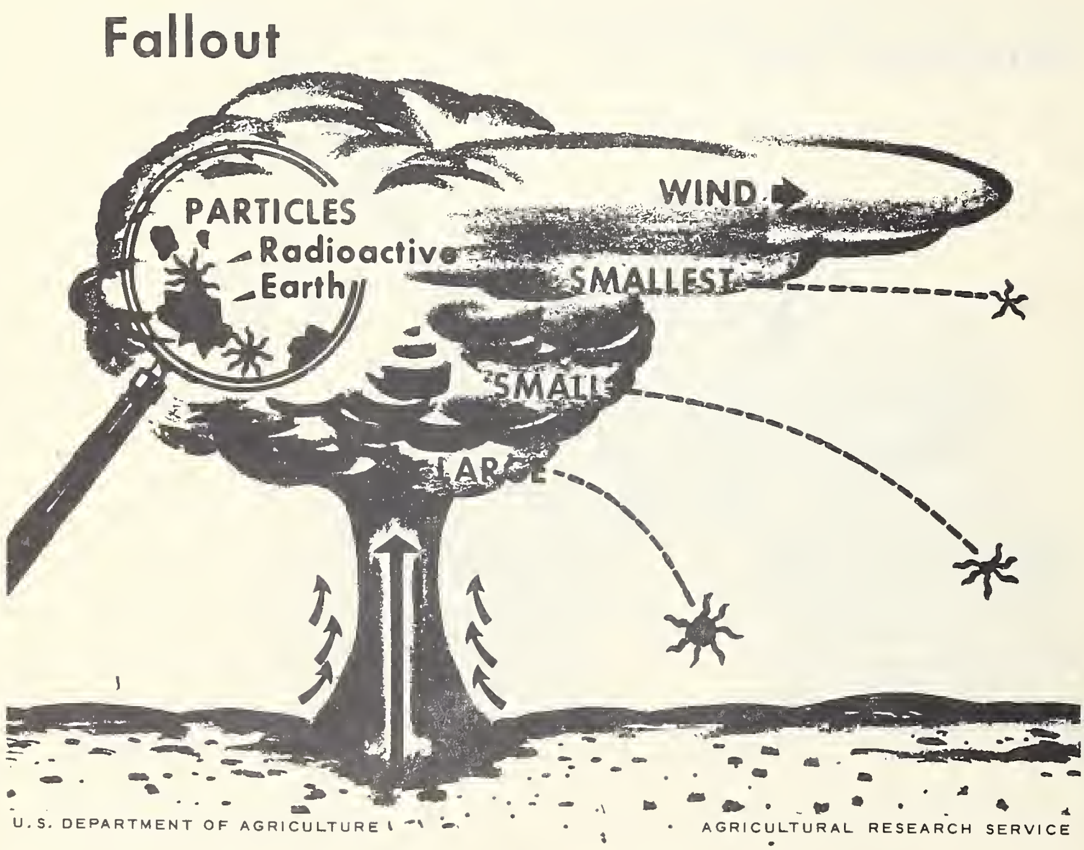


(Figure 1)

The area of destruction resulting from the blast, heat, and initial radiation will vary with the size of the bomb, the height of the explosion, and - to some extent - the terrain and atmospheric conditions. The size of the large bombs developed since World War II are expressed in terms of megatons. A megaton has the energy equivalent of 1 million tons of TNT.

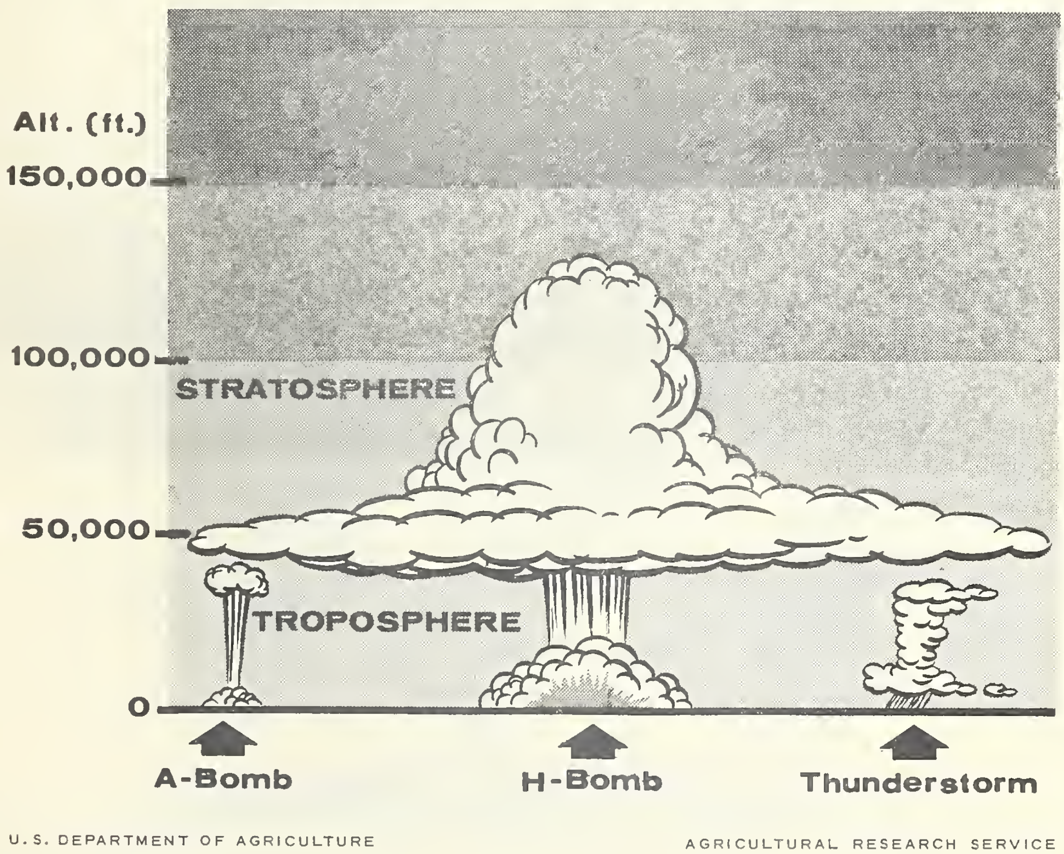
When a nuclear explosion occurs close to the ground, particles of earth, debris, and radioactive portions of the bomb - amounting to thousands of tons of material - are taken up into the familiar fireball and rise in the mushroom cloud. The maximum temperature of the fireball approaches that of the center of the sun - millions of degrees Fahrenheit. In the fireball, the particles of material are converted to gases and liquids. As these condense and solidify during cooling, they entrap radioisotopes formed from the bomb materials, and the resulting particles are thereby made radioactive. Other particles will not fuse, and may collect radioisotopes on their surfaces.

The heavier bits of debris begin falling in the immediate area shortly after the detonation and may continue for several hours depending on the meteorological conditions. (Figure 2).



(Figure 2)

According to estimates, about one-half the fallout from an atomic explosion will return to the earth's surface in about 12 hours. The remainder may go high into the atmosphere - some may go even above the troposphere into the stratosphere - and gradually descend as fallout over a period of days or years. The size of the fallout particles, together with the wind, rain, and other atmospheric conditions, will determine largely when and where they will fall to the earth's surface. The fallout is a source of radiation that can be damaging to an area when it falls in large quantities. (Figure 3).

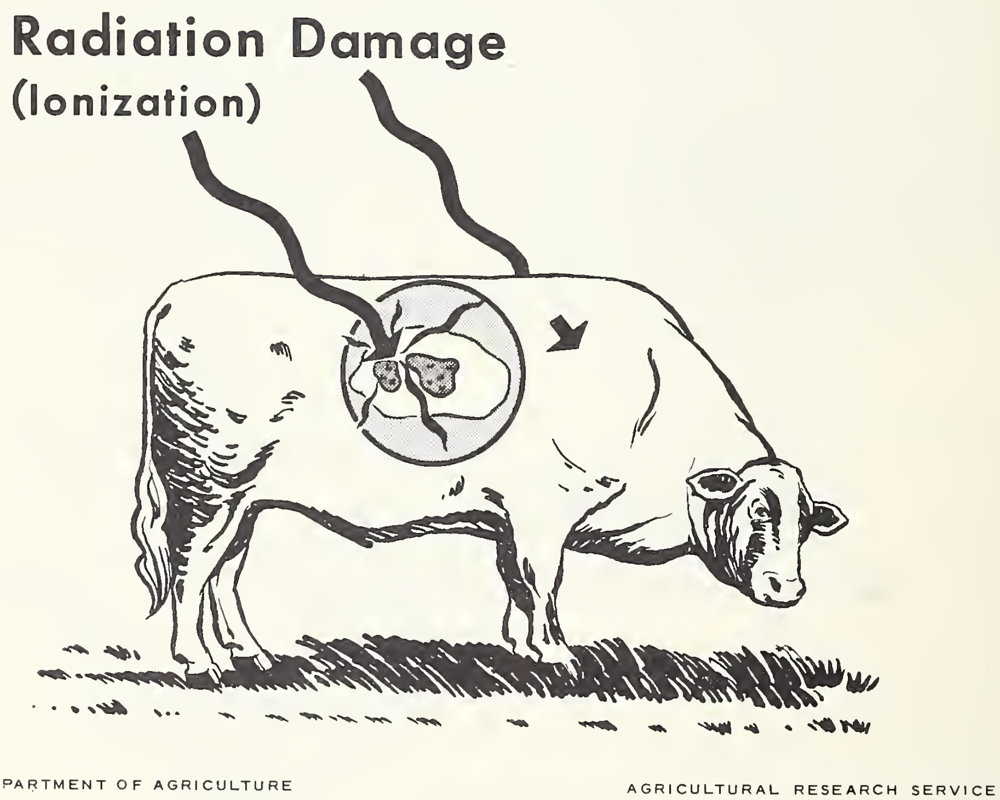


(Figure 3)

In very general terms the region of severe local fallout contamination can be described as an elongated, cigar-shaped area extending downwind from the point of burst. The pattern will be extremely irregular in outline and contamination within the area is usually not uniform. There may be local areas of extreme danger, others with very little contamination, and all gradations in between. We can speculate on the causes for these variations - air currents, rain, and other weather conditions - but the exact cause is not certain.

NUCLEAR RADIATION

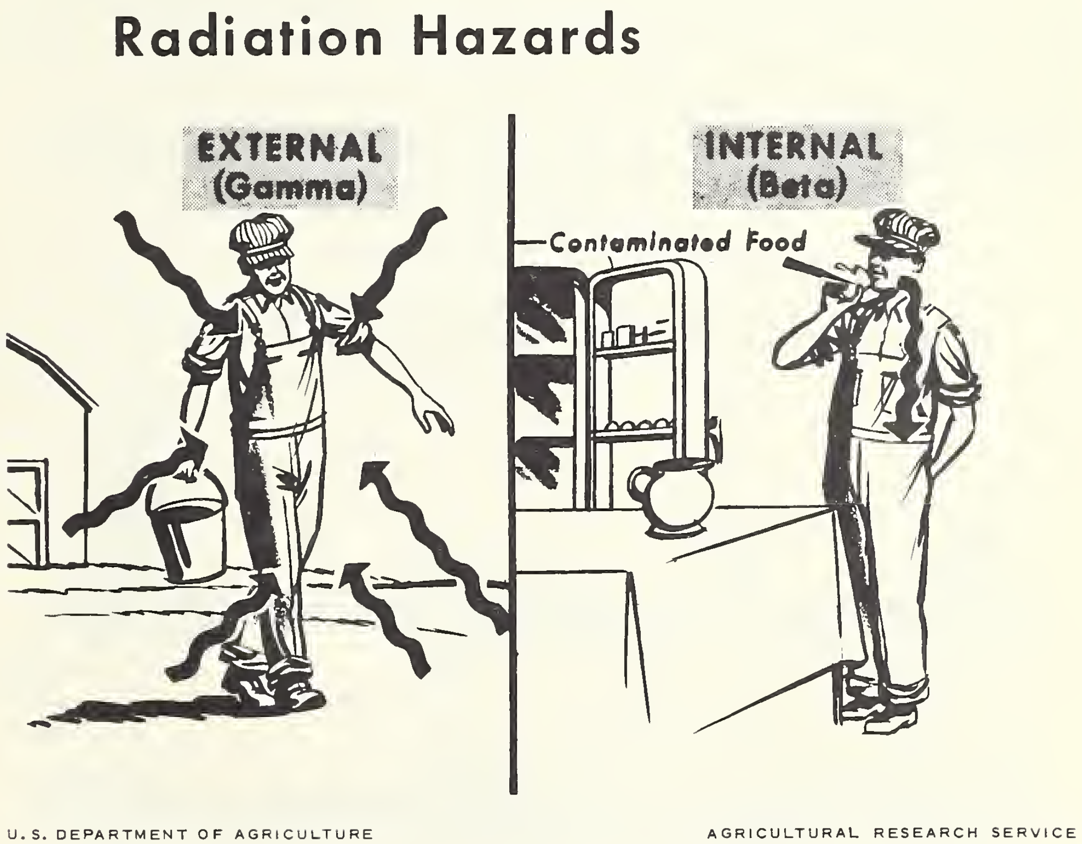
The danger of radioactive fallout is from the nuclear radiation emitted by radioisotopes produced by the explosion of the bomb. This radiation can pass into and through matter. When it does, it can change, damage, or destroy living cells through ionization - the production of electrically charged particles from cell constituents. Ionization resulting from radioactive fallout damages and destroys some of the constituents essential to the normal functioning of body cells. It forms products that may act as poisons to these cells. Furthermore, cells may lose their ability to divide and grow, thus inhibiting normal cell replacement in the body. (Figure 4).



(Figure 4)

Thus nuclear radiation can damage or affect both living and inanimate matter, but it does not transmit the radioactivity to the affected matter. In our problem, the radioactive contamination is in the fallout itself. Once it has been removed, the irradiated materials are not contaminated thereafter, but the radiation damage to the living matter may persist or may not appear until later.

We are most concerned, of course, about the harmful effects of ionizing radiation produced in the cells of living tissue and biological systems. There are two types of hazards to animal tissue created by radioactive fallout materials: (1) External radiation and (2) Internal radiation. (Figure 5).



(Figure 5)

External radiation is the acute problem that would be faced at the time fallout first drops on an area. The major concern is with the shorter life isotopes that produce gamma rays, capable of traveling long distances. Internal radiation is the chronic problem created largely by the consumption of contaminated food and water. It is caused chiefly by longer life isotopes that produce beta rays which are capable of traveling only short distances. Once inside the body, they can continue to damage the cells with which they come in contact. This radiation hazard is of major concern to agriculture since it can affect most food commodities.

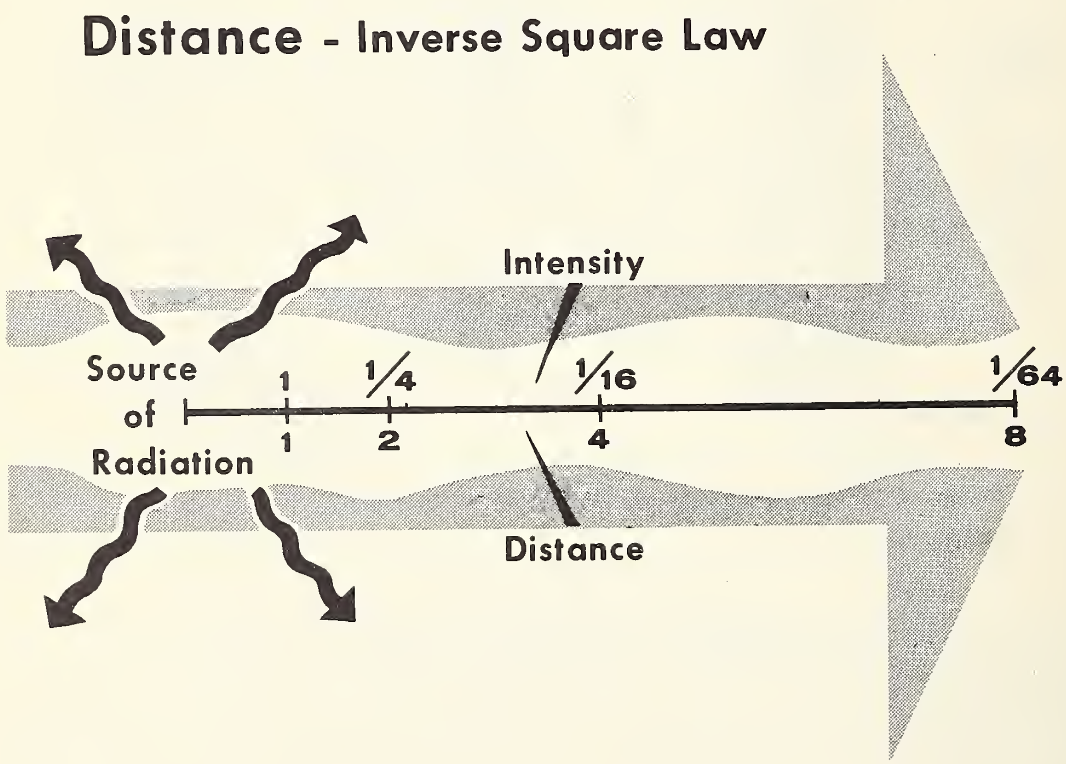
Protection against both types of hazard are available.

PROTECTION FROM EXTERNAL RADIATION

There are three basic principles of radiation protection against external sources: Distance, time, and shielding.

Distance

The first natural protection is distance. As would be expected, the radiation exposure from a nuclear explosion or from fallout is less the farther away you are from the point of the burst or the source of radiation. This is true because the radiation is spread over larger and larger areas and diluted in strength as it travels away from the original point. The general formula applied is that the dose of radiation decreases through distance according to the inverse square law. (Figure 6).

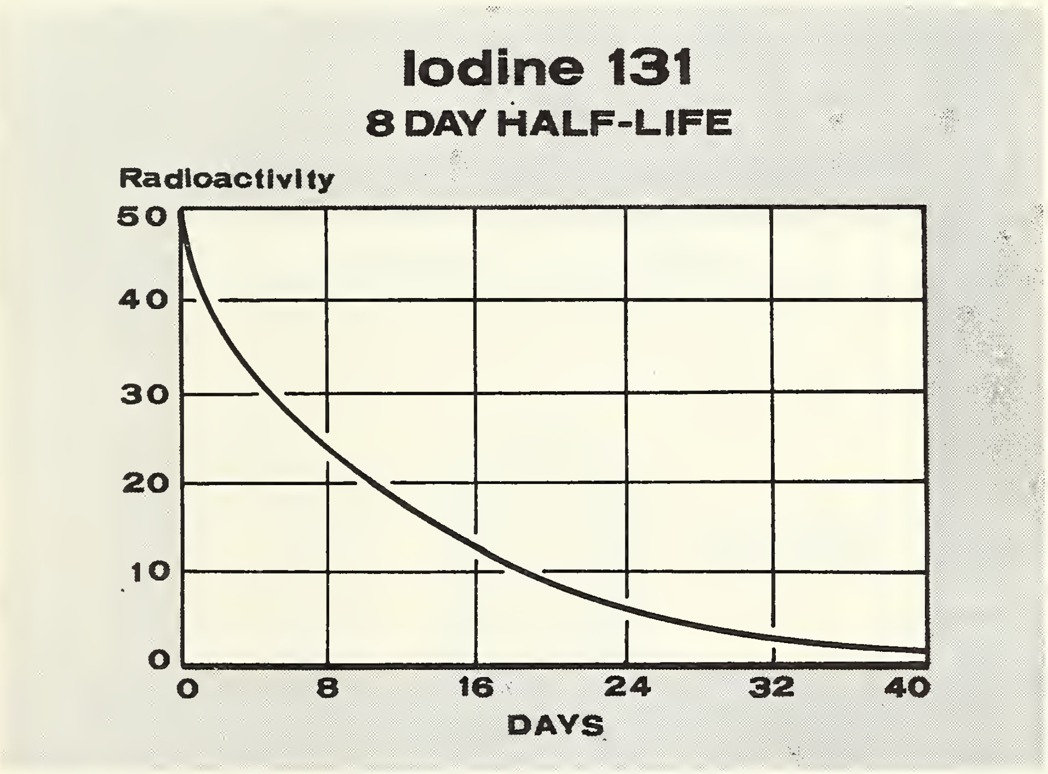


(Figure 6)

Time

The lapse of time is a natural protection against radioactive fallout. The total radiation hazard of the fallout begins to decrease immediately after its deposition. The various radioactive elements included in the fallout cloud decay at different rates, usually expressed in terms of

their half-lives. Some isotopes lose half their radiation strength within seconds, hours, or days. Others decay at a much slower rate. For example, iodine 131 has a half-life of 8 days, while strontium 90 has a half-life of 28 years. In other words, iodine 131 has decayed to half its strength in 8 days while it takes 28 years for strontium 90 to lose half its original radioactivity. (Figure 7). Therefore, the total radioactivity of fresh fallout decreases rapidly at first, but the rate of decay slows to a very low level after the shorter life elements have lost their radioactivity. (Figure 8).



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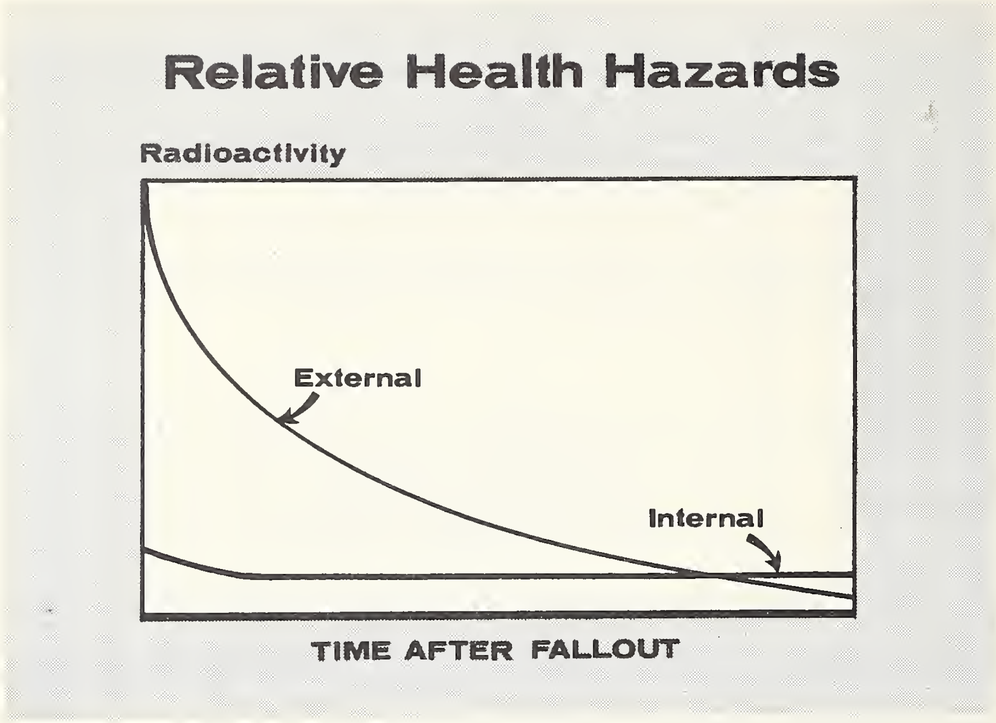
(Figure 7)

An approximate rule has been developed to estimate the decay rate of the mixture of all isotopes developed from a nuclear explosion. This rule follows that for every sevenfold increase in time following the detonation the radiation activity decreases by a factor of ten. Using this assumption, a dose rate of 1000 roentgens per hour at H + 1 hour will decay to 100 r/hr at H + 7 hours, to 10 r/hr at H + 49 hours, to 1 r/hr at H + 343 hours (approximately 2 weeks) and to 0.1 r/hr at H + 14 weeks. The 0.1 r/hr exposure can be accepted in an emergency as relatively safe for work which must be carried on out-of-doors. This would result in about 1 r/day exposure since part of the 24 hours would be spent indoors. (Figure 9).



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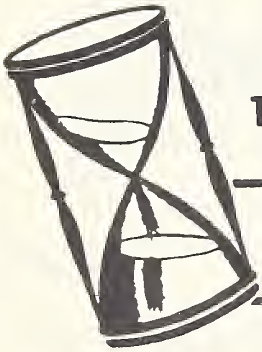
(Figure 8)

Time - Decay



TIME (hr.)	DECAY	RADIATION INTENSITY
1	—	1,000 r
7	1/10	100 r
7X7 = 49 (2 days)	1/100	10 r
7X7X7 = 343 (2 wks)	1/1,000	1 r

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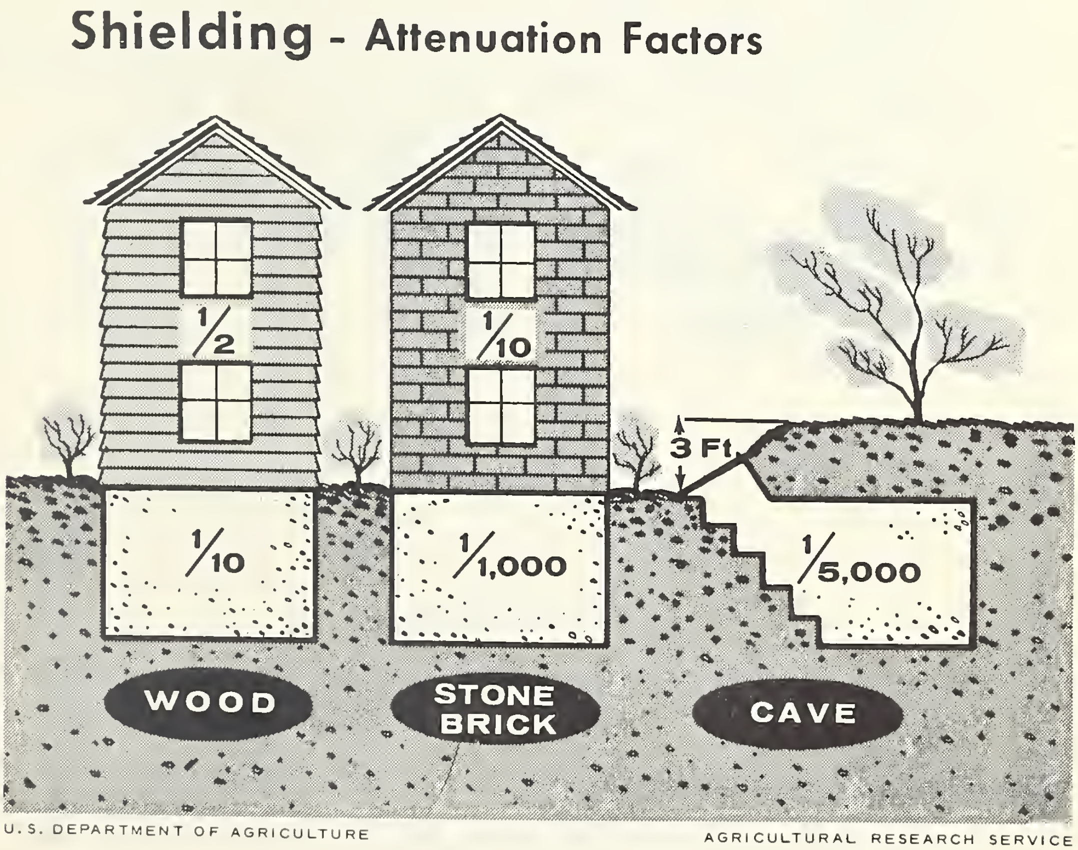
(Figure 9)

Shielding

The third protection is shielding. Farmers should be prepared to provide shelter from fallout for their families and livestock, as well as for their food, feed, and water. The most critical period of danger from radioactive fallout is the first 48 hours after detonation. However, in areas affected by heavy radioactive fallout, farmers should be in a position to provide shelter and uncontaminated food and water for their family and animals for longer periods. It might be advisable to stay within shelter - at least most of the time - for as much as a week or two.

Research experience indicates that a person on the first floor of an ordinary frame house in a fallout area would acquire about one-half the radiation dose received out-of-doors without any protection. Adequate protection would be found in an underground shelter with a covering of earth at least three feet thick. (Figure 10).



(Figure 10)

Decontamination

Since radioactive materials cannot be destroyed, decontamination involves the transport of the source of radiation or contamination. The fallout should be removed from a location where it is a hazard to a place where it can do little or no harm. Thus, there are two procedures: (1) removal and (2) disposal. (Figure 11).

(Figure 11)

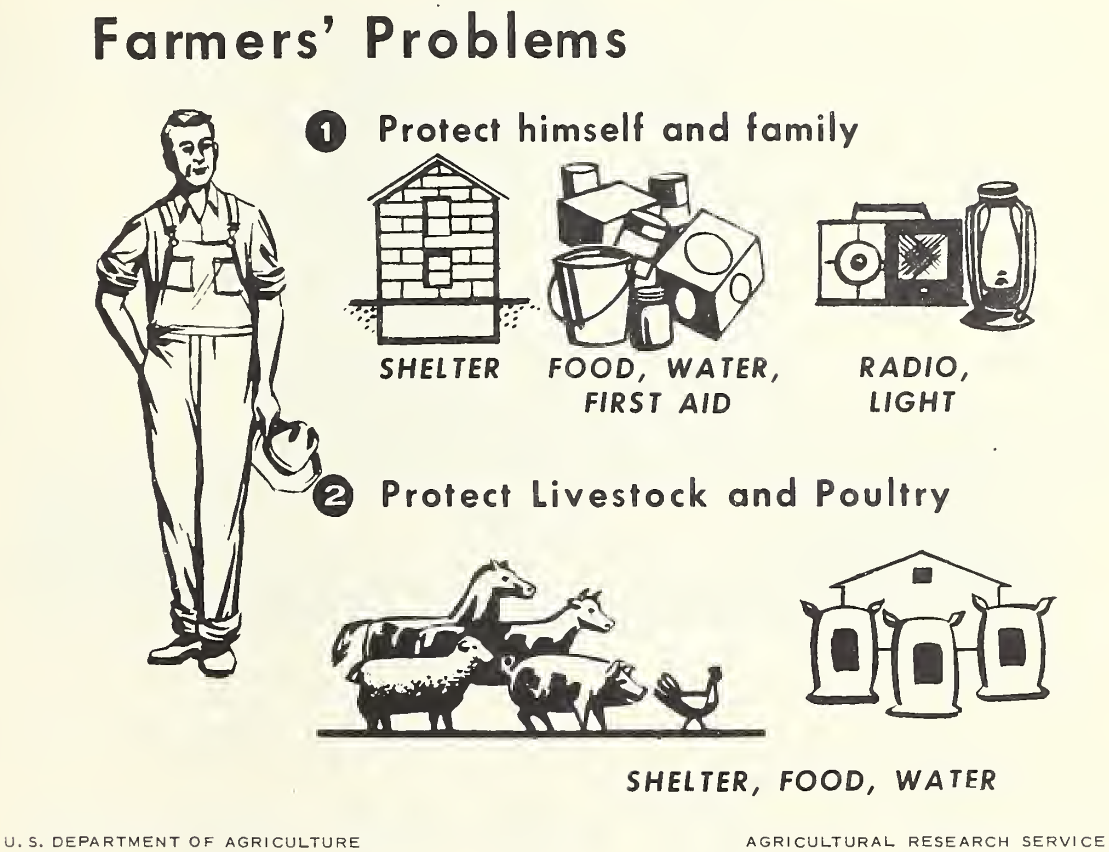
Farmers' Problems

The farmer has two major responsibilities in the event of a nuclear attack.

First, to provide protection for himself and his family from radiation and fallout. He must provide adequate shelter, food and water (at least two-weeks' supply), sanitary facilities, and a battery radio or some other means of receiving emergency information.

Second, he should provide protection for his livestock and poultry from radiation and fallout. This protection would include shelter, uncontaminated food and water, and buildings and other facilities for

confinement until the radioactivity outdoors decays to a level that would be relatively safe for the livestock to be turned out. (Figure 12).



(Figure 12)

For livestock, a good tight barn would reduce radiation dosage about one-half. But any kind of shelter provides some degree of protection. Proper use of shelter for animals can reduce the number of deaths from radiation by 75 percent or more. (Figure 13).

Field experiments have indicated that total body radiation exposure of animals to from 300 to 600 roentgens provides a mid-lethal dose - or the dose level which you could expect to kill 50 percent of the animals within 30 days. However, there is a variation of tolerance among species of animals.

Table I gives the percent mortality of various species of unsheltered animals affected by exposure to different intensities of radiation.

TABLE I

PERCENT MORTALITY OF VARIOUS SPECIES OF UNSHELTERED ANIMALS FOLLOWING EXPOSURE TO A 24-HOUR RADIATION DOSE

	Percent Mortality				
	100%	80%	50%	20%	0%
Species	Exposure Dose in Roentgens*				
Cattle	790	690	600	510	400
Sheep	690	600	520	440	350
Swine	610	530	460	390	310
Poultry	1000	920	800	680	540

*Exposure dose in area where livestock and building are located.

Table II shows the effects of shielding, using a two-story basement type barn with a loft filled with hay.

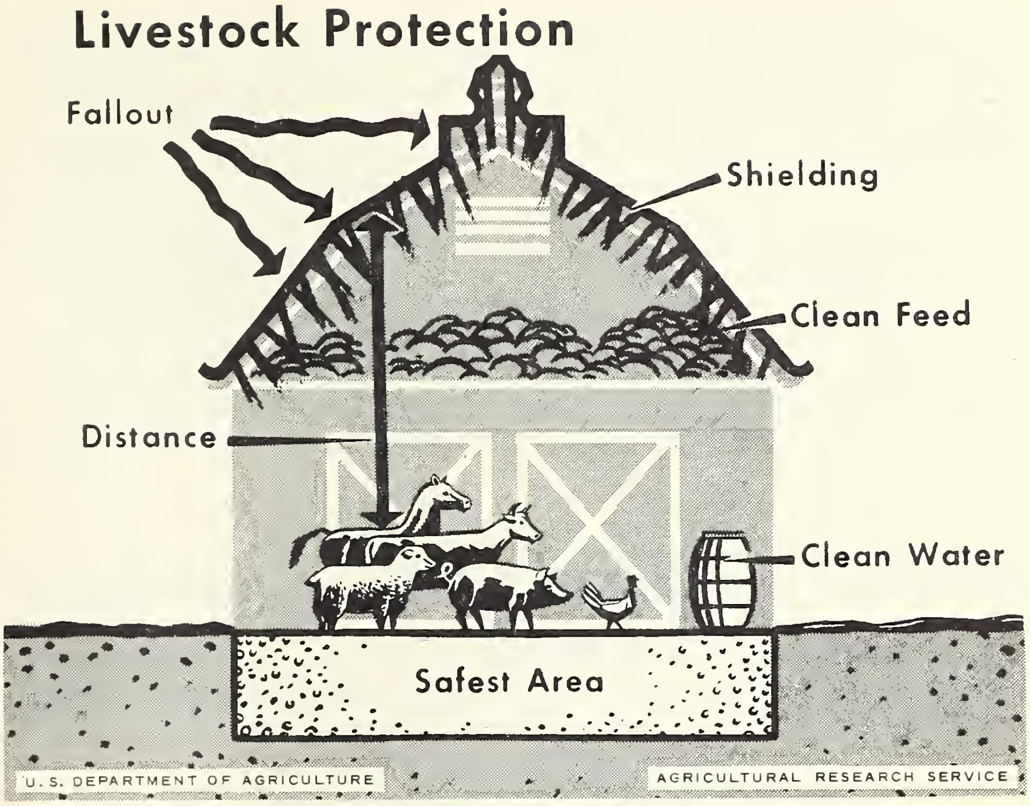
TABLE II

PERCENT MORTALITY OF VARIOUS SPECIES OF SHELTERED ANIMALS FOLLOWING EXPOSURE TO A 24-HOUR RADIATION DOSE

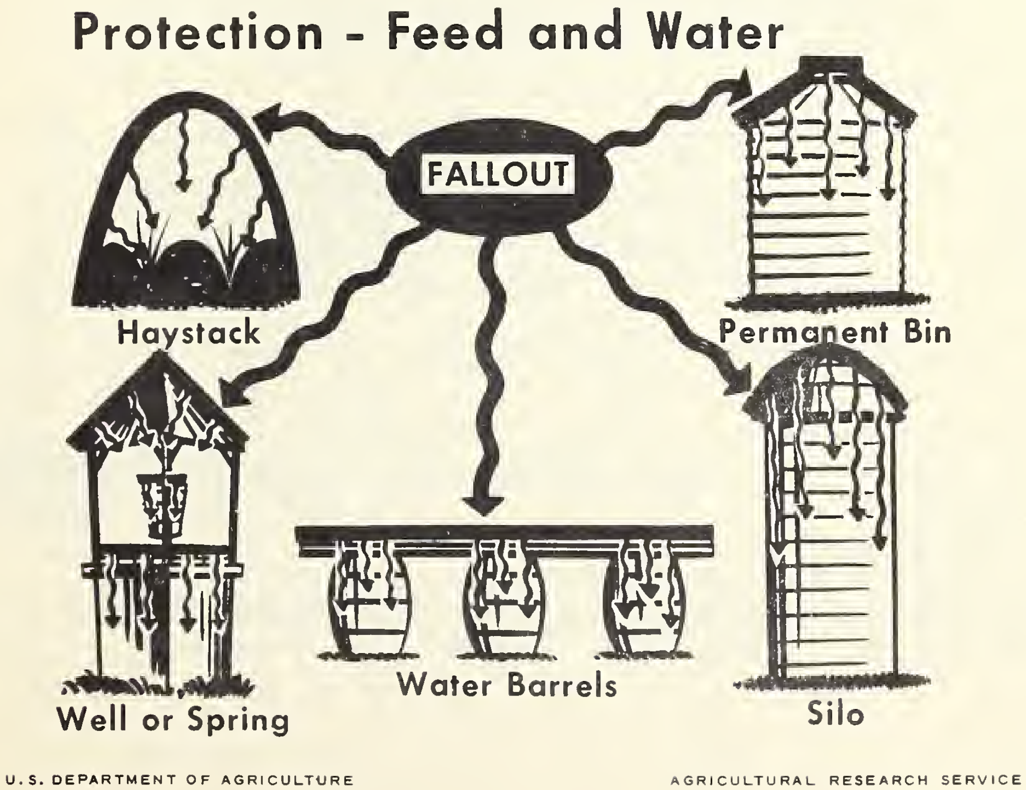
	Percent Mortality				
	100%	80%	50%	20%	0%
Species	Exposure Dose in Roentgens*				
Cattle	3900	3400	3000	2500	2000
Sheep	3400	3000	2600	2200	1700
Swine	3000	2600	2300	1900	1500
Poultry	5000	4600	4000	3400	2700

*Exposure dose in area where livestock and building are located.

In protecting feed and water, the objective is to prevent the fallout, which is the source of radiation, from becoming incorporated into the materials. This can be done by placing a cover over the feedstuffs or water. Grain stored in a permanent bin or ensilage in a silo are provided with adequate protection against fallout and the contents can be safely used when the farmer is able to get into the area to use them. The haystack in an open field can be protected with a covering such as a tarpaulin. The fallout will lodge on the tarpaulin, irradiate the hay - just as it does the contents of the feed bin and silo - but by carefully removing the tarpaulin, the radioactive fallout will be removed. Although the hay would be irradiated, it would not be radioactive and could be used as a safe source of feed for livestock. (Figure 14).

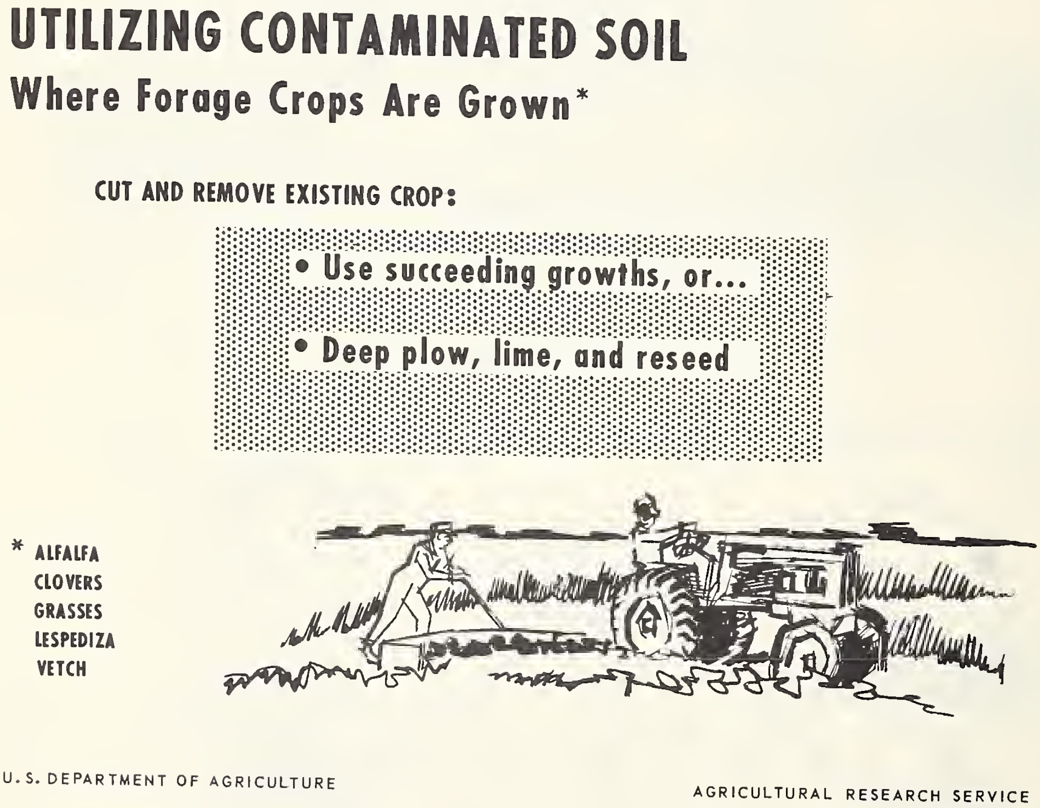


(Figure 13)



(Figure 14)

The use of standing crops such as grain, fruits, and vegetables subjected to fallout will depend upon the stage of growth - that is, whether they can be allowed to stand until radioactivity has decayed enough to make it relatively safe to get to them to harvest. If fallout is heavy, ripe, thin-skinned fruits may be lost because of the personal hazard involved in harvesting them. Thick-skinned fruits that do not have to be picked immediately and that can be peeled before eating, can probably be saved. They can be decontaminated with washing agents before marketing. Orchard trees should be maintained and the fruits examined for radioactivity before and after harvest. Leafy vegetables such as lettuce should not be eaten unless they are thoroughly washed and are known to be free of hazardous amounts of radioactivity. Growths of alfalfa and other feed crops standing in the fields at the time of the fallout might not be usable. Subsequent growths would be less radioactive. (Figure 15).



(Figure 15)

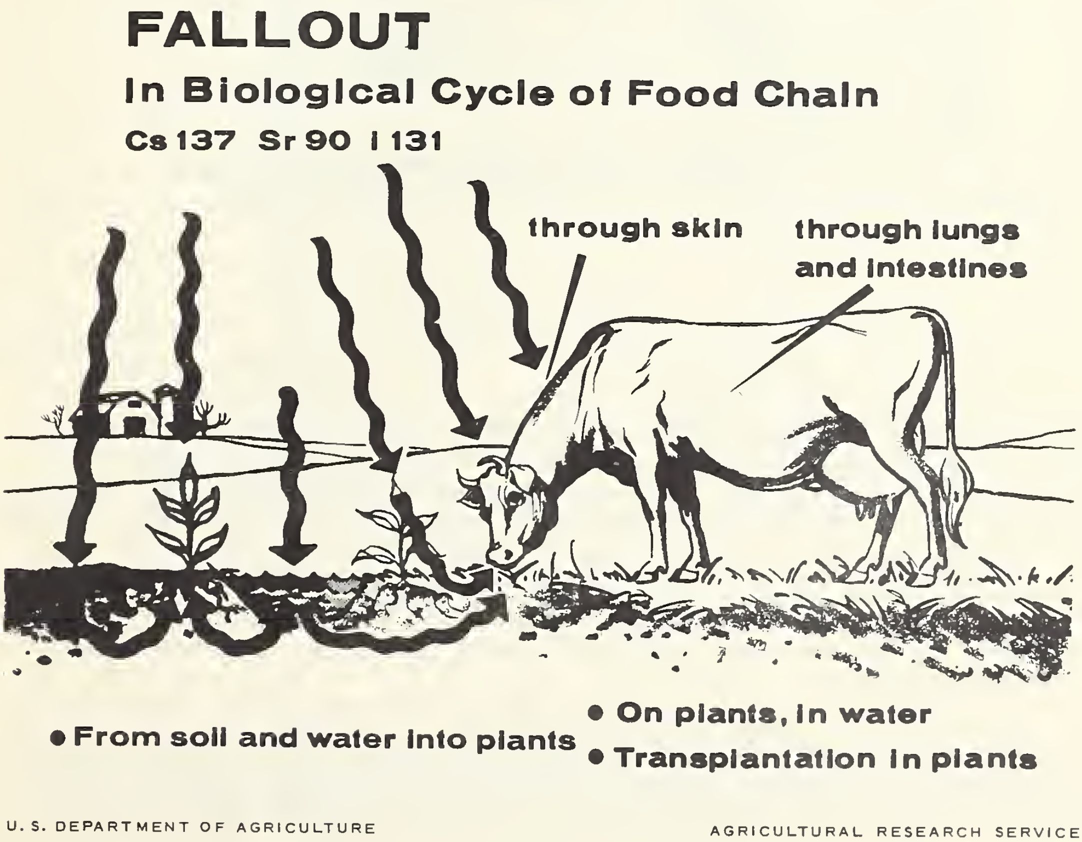
Meat animals subjected to fallout may be thoroughly washed off to remove the external radioactive particles. If they are needed for food, they may be slaughtered immediately and the hides carefully discarded to prevent contamination of the edible parts. Because of the ingested and

inhaled fallout, it will be necessary to discard the respiratory organs and the entire alimentary tract, along with the contaminated hide. The disposition of these contaminated parts should be determined after a more thorough radiological examination. If the area has been subjected to sub-lethal amounts of fallout, animals may develop signs of radiation sickness. In this case, they might be placed on clean, uncontaminated pasture and treated symptomatically.

HAZARDS OF INTERNAL RADIATION

The second phase of radiation hazard from fallout is internal radiation or the chronic exposure to the long-life radioactive isotopes, especially those that find their way into the food chain. These radioactive elements generally enter the bodies of animals and human beings with food and water.

At first, the principal source of internal radiation is edible plants contaminated externally when the fallout first drops on the affected area. For livestock this would involve primarily forage grasses and legumes. For man it would involve fruits and vegetables. As time passes, and the contaminated food and feed are discarded, the principal source of internal radiation for animals and man is from the contamination in the soil which is absorbed through plant roots. (Figure 16).



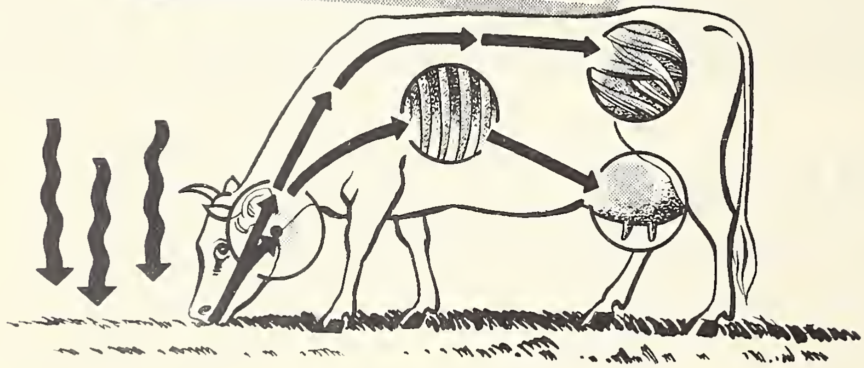
(Figure 16)

The radioactive isotopes of most significance as internal radiation hazards are iodine 131, cesium 137, and strontium 90. Many others produced by nuclear explosions are of minor concern because of the small amounts available, their extremely short half-life, and the fact that they are not incorporated into the food chain and hence do not affect animals and man. (Figure 17).

Long-Lived Isotopes

BIOLOGICAL EFFECT

	Distribution	Removal
Cs 137	Soft Tissue	Urine
Sr 90	Bones, Milk	Feces
I 131	Thyroid	Urine



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(Figure 17)

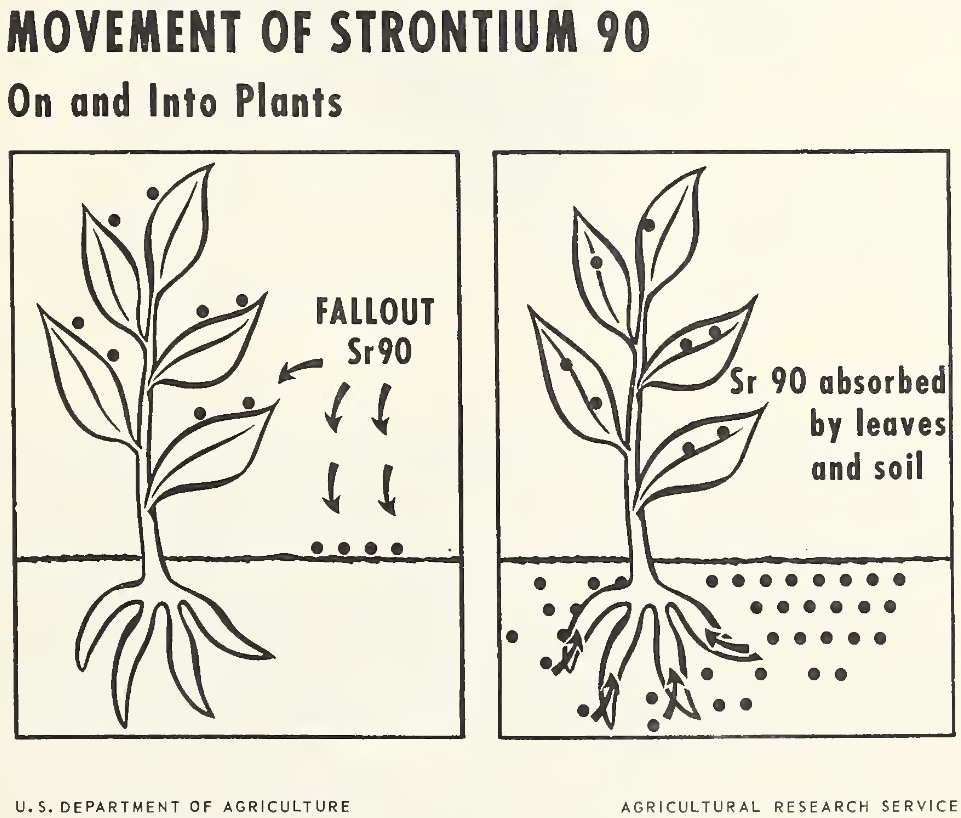
Radioactive iodine is very similar to ordinary iodine. When it is consumed with contaminated plants it gets into the biological system. It collects in the thyroid gland. Children are more susceptible than adults to thyroid damage by radioactive iodine. In mammals it can be transferred to milk. Fortunately, this isotope has a relatively short half-life of 8 days. Its radiation hazard has virtually disappeared in about 60 days. While the early acute hazards may be serious, there is general agreement among research scientists that iodine 131 will not be an important long-term fallout hazard.

Cesium 137 has a long half-life of 30 years and is somewhat similar to the essential nutrient element potassium. When it is consumed and absorbed, it is found primarily in muscle tissue. But this radioisotope is not

retained long in the body. It continually enters and leaves the system just as potassium.

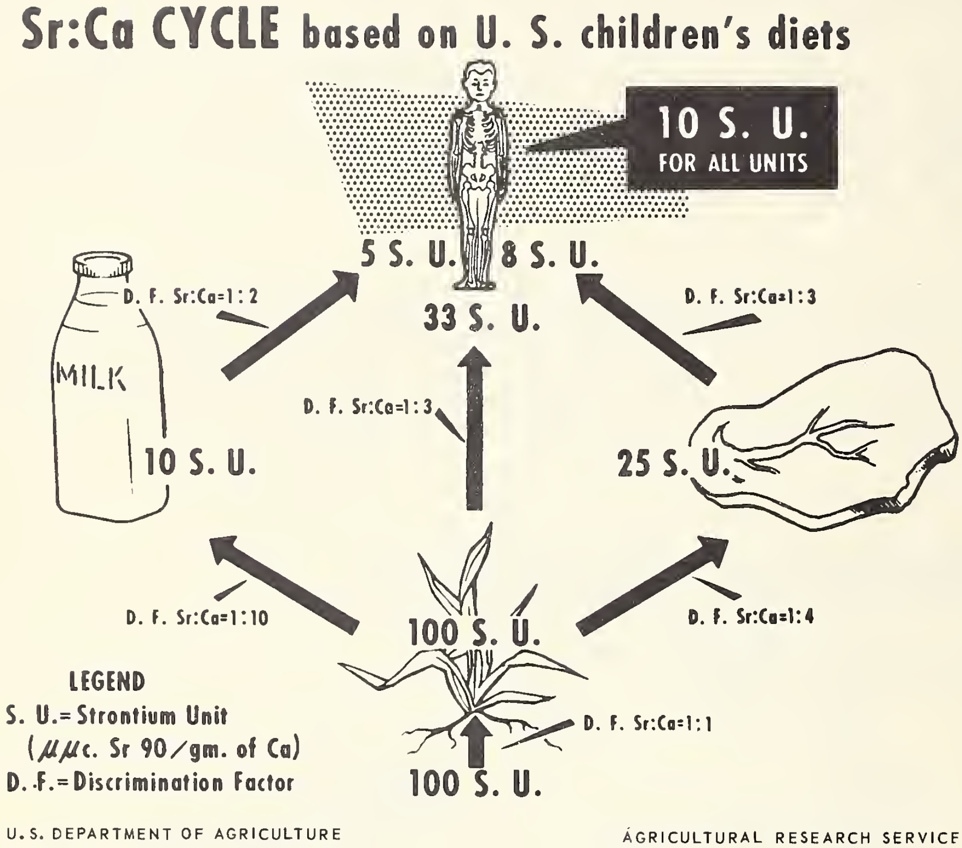
Strontium 90, however, with a half-life of 28 years, is of primary importance. It behaves much like calcium in soils, plants, and animals. Atomic explosions produce large amounts of strontium 90. It is taken up in biological systems, secreted in milk, and collects in bones, where it remains for a number of years.

Just as other radioactive isotopes of fallout, strontium 90 falls on the surface of plants and can be consumed with contaminated foods and forage. Some of it enters the soil, remaining for considerable periods in the top several inches of uncultivated land. From here it is taken up by plants along with calcium, and when the plants are eaten by animals the radioactive strontium enters the bone and milk. (Figure 18).



(Figure 18)

Fortunately, there is a protective factor termed the "discrimination factor." As the strontium and calcium move together through the food chain from the soil to the plant, through the body of animals to the meat and milk, and then through the body of man to its resting place in the bones, relatively more calcium than strontium is left. This is the

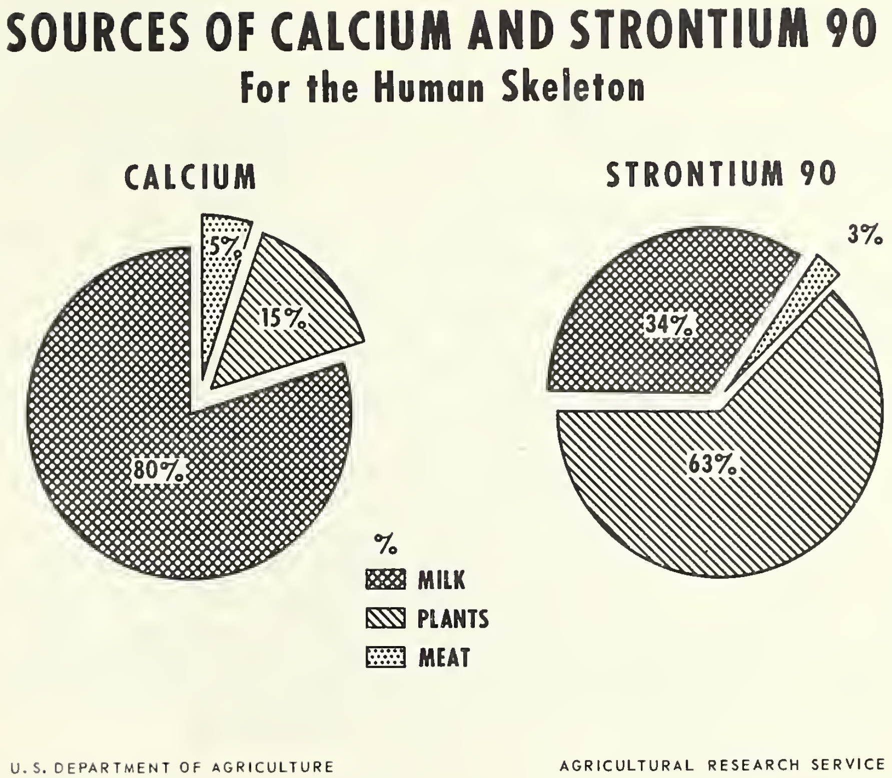


(Figure 19)

natural discrimination between calcium and strontium. The findings of Comar show that if there are 100 units of strontium to each 100 units of calcium in plants, only 8 to 16 units of strontium for each 100 units of calcium would enter the bones of the human population. (Figure 19).

Nutrition experts estimate that within the United States, from 70 to 80 percent of the calcium intake in our average diet comes from milk and dairy products. As the biological systems of both the cow and man discriminate between calcium and strontium, human bones accumulate only 34 percent of its hazardous strontium while it is getting 80 percent of its calcium from milk. From plants, the human bones get 15 percent of the necessary calcium while it is collecting 63 percent of the strontium content. In addition, we get about 5 percent of our calcium and 3 percent of the strontium 90 from meat. (Figure 20).

Therefore, because milk is the outstanding food for building healthy bones and teeth, it would not be wise to recommend the substitution of another source of calcium in our diets, except under conditions of extreme



(Figure 20)

emergency. In fact, the evidence available at this time would indicate that it is better to continue getting more of our dietary calcium from milk and less from plants.

(To digress for a moment - radioactive iodine is seriously damaging to young children and would be contained in milk produced in fallout areas. Therefore, milk from contaminated areas should not be consumed by children for about sixty days after the nuclear explosion to allow time for the decay of radioactive iodine. Such milk, under emergency conditions, need not be destroyed but can be converted into dairy products and stored for at least sixty days or until the radioiodine has decayed).

Radioactive isotopes of strontium deposited in the bone probably can produce serious consequences, including bone cancer and leukemia. But since radiostrontium is assimilated in the bones, it constitutes essentially no genetic hazard for its radiations do not reach the reproductive organs in any quantity.

The question of whether there is a level of ionizing radiations under which there are no harmful effects to man has received considerable attention by many investigators. The results as of today are generally inconclusive because measurements at low radiation levels are difficult to make. In general, the maximum concentration of strontium 90 in the bones recommended by the National Committee on Radiation Protection and Measurement for atomic industry workers is one microcurie (very small measure of radiation) for a man whose body is estimated to contain 1,000 grams of calcium. Experiments with the reaction of animals to radiation indicate that appreciable increases in the number of bone tumors should not be expected to appear at less than 10 times this level. The average daily maximum permissible concentration (MPC) for peacetime consumption of food and water has been 80 strontium units. A strontium unit (s.u.) is one micromicrocurie of strontium 90 (Sr^{90}) per gram of calcium - or a millionth of a millionth of a curie of Sr^{90} per gram of calcium. The MPC is based on continuous intake. It was set by the International Commission on Radiation Protection.

Human beings under normal conditions constantly receive radiation from many sources. Cosmic rays, X-rays, potassium, and radium present in earth, bones, and wrist watches are a few of these sources. This background radiation contributes about two percent of the maximum level adopted by the International Commission on Radiation Protection as acceptable for large segments of the general population.

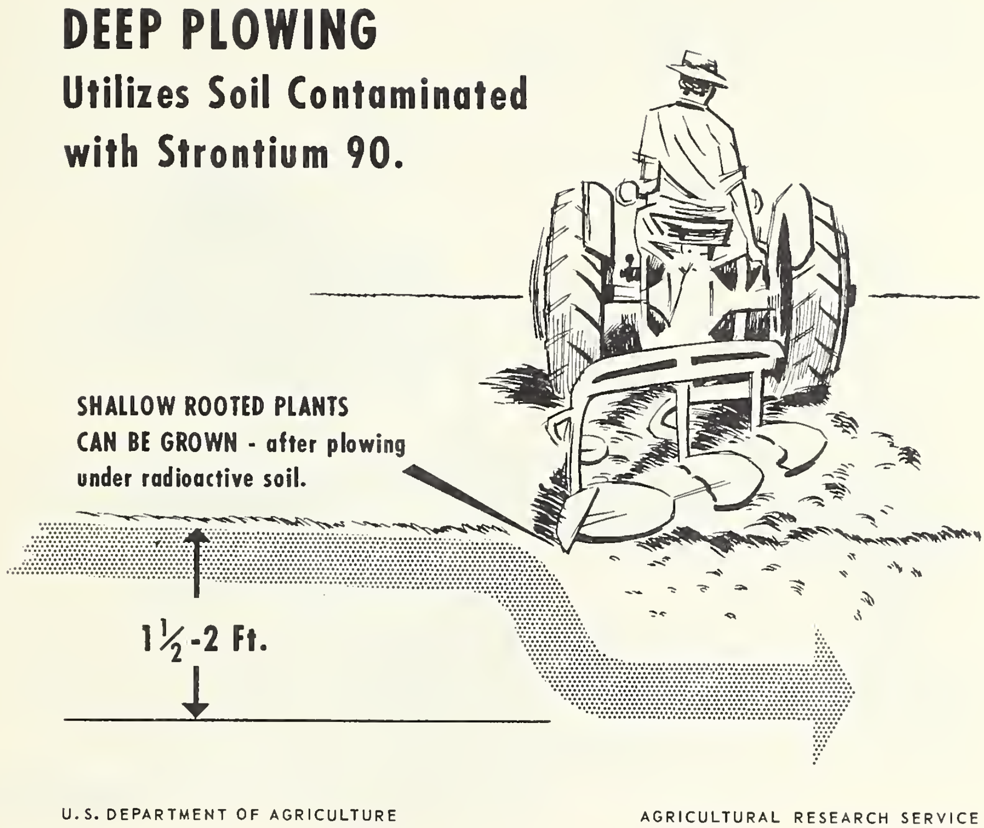
The exact long-term results of chronic exposure to internal radiation created by multi-bursts of modern nuclear weapons, under emergency conditions of an attack on populated areas, are not known.

RESEARCH

Reclaiming Radioactive Soil

Federal agencies and laboratories, universities, and Agricultural Experiment Stations conduct research and studies on the effects of radioactive fallout and measures for decontamination. The Department of Agriculture, in cooperation with the Atomic Energy Commission, is conducting investigations on methods of reclaiming radioactive soil for use in the production of food in the event of catastrophic fallout. Among the methods that have been examined or are being studied are (1) deep plowing, (2) diversion to other uses, (3) surface soil removal, and (4) protective mulches.

Deep plowing would be aimed at turning the contaminated surface soil under to a level of one foot or more - or below the root zone of the plants that are to be grown. Deep plowing may reduce the uptake of strontium 90 in shallow rooted crops such as grasses and many vegetables. However, before it is used, careful evaluation should be made of the situation in the area and the possible alternatives. Once strontium 90 has been plowed under, it is in the soil virtually permanently and no method of future removal is known at this time. (Figure 21).



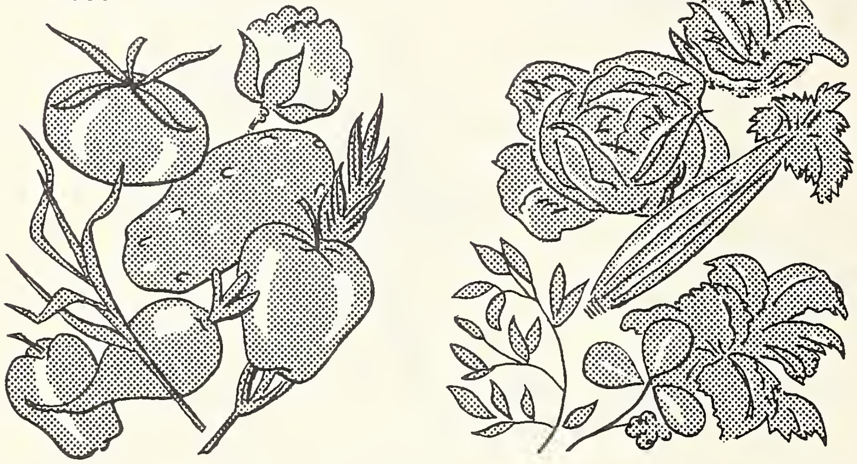
(Figure 21)

Diversion of the soil to other uses may mean changing the species of crop grown on the land. The quantity of strontium 90 absorbed could be reduced by growing crops with low concentrations of strontium and calcium in their edible tissues. However, since plants are a source of calcium, this measure would result in the calcium content of diets being reduced. Unless alternative sources of dietary calcium were provided, cultivating low-calcium crops would have obvious limitations. However, in wartime emergencies survival might be aided by this procedure. Potatoes which contain about 10 milligrams of calcium per 100 calories, are a particularly suitable crop in contrast to leafy vegetables, which may contain 10 to 100 times that amount of calcium per 100 calories. (Figure 22).

If the top several inches of the soil are contaminated with strontium 90, deep rooted plants may be grown with little up-take of the radioactive material because they draw their nutrients from below the contaminated level. (Figure 23). For example, contaminated land could be taken out of shallow-rooted forages or crops and be used for producing such deep-rooted crops as alfalfa. Another diversion might be to take land out of direct food production and use it for cotton fiber, flax, castorbeans, timber, or other non-food production. If the land is too heavily contaminated, it might have to be taken out of agricultural production for an indefinite period.

SUBSTITUTE CROPS
Having Low Calcium Content

LOW Grow These	HIGH Not These



Potatoes, cereals, apples, tomatoes, peppers, sweet corn, squash, cucumbers

Lettuce, cabbage, kale, broccoli, spinach, turnip greens, celery, collards

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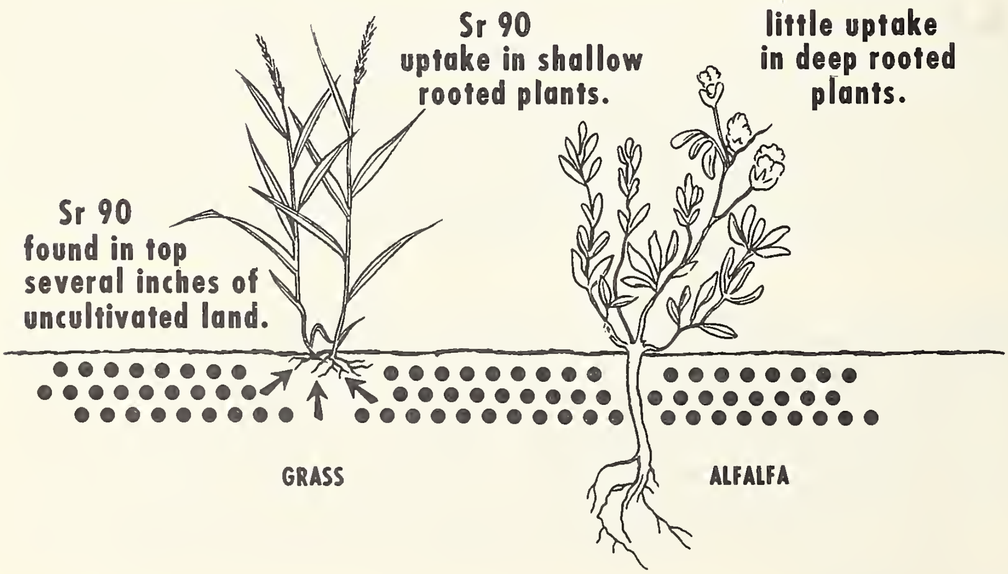
(Figure 22)

ROOT DEPTH
Affects Strontium 90 Uptake



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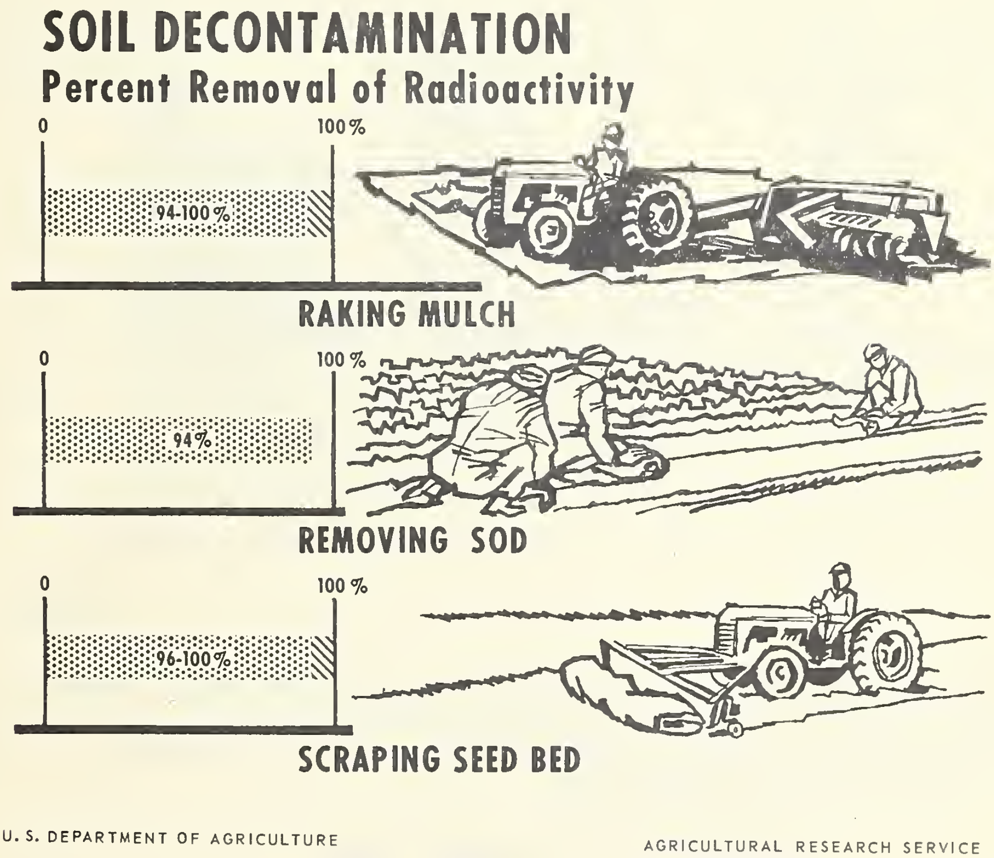
(Figure 23)

Removing the contaminated surface soil by scraping has been from partially to highly successful, depending on the roughness of the land. By carefully removing the contaminated surface and burying the radioactive soil in an isolated area, the land may be reclaimed for some use. The method might be expensive and - with the procedures developed at this time - not suitable for large acreages. It might be useful if small clean areas are seriously needed to produce food for survival. (Figure 24).

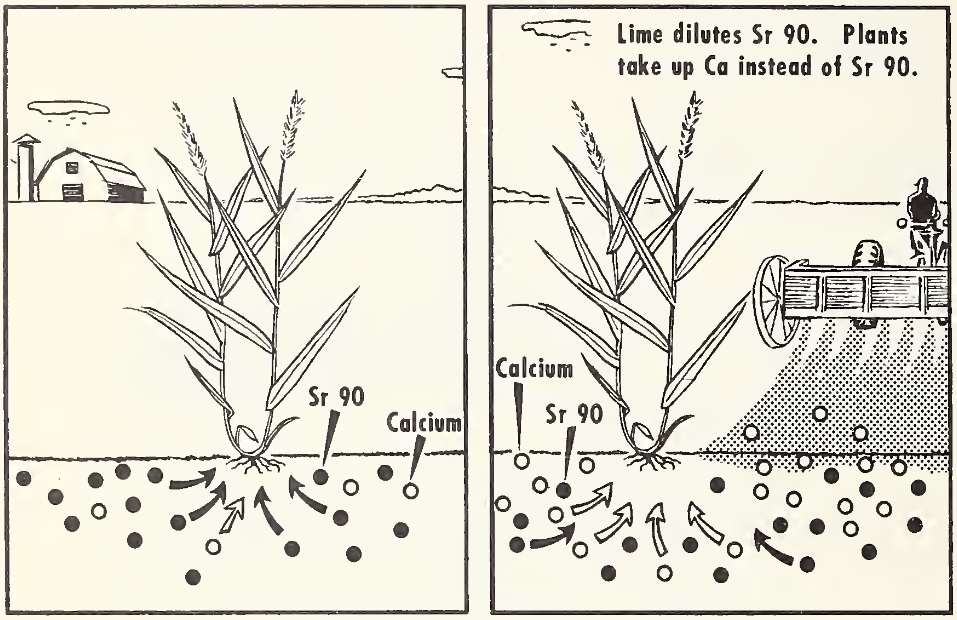


(Figure 24)

Mulches of various thicknesses have been tested. Raking and removing heavy contaminated mulches from experimental plots cleaned up nearly all radioactivity, though a little more was left on the soil from light and medium mulches.

Still another method of making contaminated soil more useful to agriculture is the addition of lime. The plant's need for calcium leads to the absorption of the similar element, strontium. In soils low in exchangeable calcium, more strontium 90 will be taken up by the plant. By liming acid soil, more calcium is made available to the plant and less strontium 90 will be absorbed. The practice would be useful on highly acid soils on which liming would be normally beneficial for other reasons. (Figure 25).

EFFECT OF LIMING ACID SOIL
On Uptake of Strontium 90



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(Figure 25)

The approach to reclaiming contaminated soil in any given area would depend on the degree of radioactivity and the needs for survival. Further tests are being conducted under a variety of land conditions and various systems of land management.

Strontium 90 in the Dairy Animal

Additional cooperative research between the Department, the Atomic Energy Commission, and Cornell University includes studies of the response of animals to daily intakes of radioisotopes with particular reference to their movement in the food chain and the resulting pathology. Present work is designed to determine the extent to which radiostrontium ingested by the dairy animal becomes incorporated and is excreted into the milk. The study also includes possible means of altering this movement and disposition of the radioisotope.

SUMMARY

In short, we find that in the event of attack with nuclear weapons, the hazards of radioactive fallout to agriculture would be serious. But there are practical methods of protection. Even in areas of heavy radioactive fallout contamination, proper shelters for sufficient periods of time can significantly reduce the damages of external radiation to man and his animals. The long-term hazard of internal radiation is less acute but does present a chronic problem of major concern. Through the knowledge being gained by research, we could expect to reduce this hazard by the proper use of the land and its products that provide the nation's food supply.